Modelling the Hungarian Agriculture: a methodological overview of the FARM-T model

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Abstract

This paper provides an opportunity for the reader to get an insight into the current modelling work at the Research Institute for Agricultural Economics, Hungary (AKI). After giving a short summary of the applied econometric models in the past decade, our latest development, the farm group model FARM-T will be introduced.

Before introducing FARM-T in details, we devote the second part of the paper to the collecting of all challenges we were facing during the model development process, when we tried to establish a model structure, with which the possible effects of the introduction of the Single Payment Scheme (SPS) in Hungary can be properly estimated. Therefore, this chapter is meant to explain our motivation for choosing the applied model concept.

In the following part of the paper, we provide a detailed introduction of the model. First, we describe the general structure, and then we go into detail about supply and demand sides. We lay an emphasis on the supply side, and especially how the agricultural production is represented by farm groups. After describing supply and demand sides, we focus on how the equilibrium is reached. Here, we discuss the interrelationships between sectors in more details (e.g. connection between crop and livestock production). We also stress the importance of regionally differentiated export and import markets. This enables us to take the various transportation modes, distances and market positions on different external markets into account.

Finally, we discuss special model building issues related to the 2003 CAP reform, especially how the effects of decoupling of direct payments from production are estimated. We close this paper with a short summary of the problems concerned.

Keywords: FARM-T, partial equilibrium model, farm groups

1. A short summary of the modelling work at AKI in the past decade

The first econometric simulation model at AKI was created during the pre-accession negotiations between Hungary and the EU. During the negotiation process, AKI played the role of helping policy decision makers by performing detailed impact analyses under different scenarios. This urgent need to estimate the possible impacts of an EU-accession on the Hungarian agriculture, forced AKI to strengthen its quantitative analysis capacity. To meet this requirement, the Hungarian Simulation Model (HUSIM) was developed by the end of the 1990's. HUSIM is a traditional partial equilibrium, supply-demand model that covers 34 agricultural sectors, and represents more than 90% of the total agricultural production. The first model based impact analysis was published in 1999 (MÉSZÁROS *et* *al*., 1999), which estimated the possible effects of the EU-accession under different "phasing in[1]" levels. Since then, HUSIM has been under constant development, and nowadays it is regularly used to estimate country level effects of different agricultural policy changes (POTORI, UDOVECZ, 2005).

After the Farm Accountancy Data Network (FADN) had been established also in Hungary – under the supervision of AKI – we had the necessary database to create a farm level model. This model, called MICROSIM (which refers to micro-simulation), uses the accountancy data of the FADN database as a direct input. MICROSIM determines possible future states of the FADN farms under different policy scenarios and macroeconomic conditions. This enables us to investigate some underlying structural changes in the agriculture and helps us to identify the type of farms in critical financial condition.

The 2003 CAP reform came with some new legislative elements that were hard to incorporate into the existing model structures (e.g. decoupling of direct payments from production). As a response, we started to design a new model in 2004, which was intended to be a tool for estimating the possible effects of these new policies. In the next part of the paper, we summarize the challenges we faced, and the concepts we applied to solve them.

2. Challenges we faced and solutions

The issues that determined the directions of the model development can be divided into two groups: (1) changes in the legislation and especially the possible effects of introducing the SPS in Hungary, and (2) special market related issues, out of which the problems on the cereal market had the greatest importance. In the following part of the paper we summarize these challenges, and present the concepts we applied to handle them.

2.1. Legislation

The conditions under which Hungarian farmers joined the common agricultural market were laid down in the Copenhagen Agreement. In 2004, Hungary and seven other New Member States (NMS) introduced the Single Area Payment Scheme (SAPS) for subsidizing its agriculture. Regarding direct payments, this system includes a single area payment (with the same per hectare value for all eligible land), and a set of coupled national direct payments (CNDPs). Additionally, the "phasing in" rule applies, meaning that the total support granted for a sector can not exceed a given percent of the support granted for the same sector in the standard scheme of the old member states. There is also the possibility for Hungary to raise support levels with an additional 30% from the national budget (however, in the first four year of the EU membership Hungary did not fully exploit this option).

Although it is possible for the NMS to maintain SAPS until 2011, the Hungarian Ministry of Agriculture is determined to introduce the Single Payment Scheme (SPS) in 1st January, 2009. The

[1] The phasing in rule declares that the total support granted for any sector cannot exceed a maximum level which is given as the ratio of that particular support in the new vs. the old member states. Exact phasing in values were laid down in the Copenhagen Agreement (70% in 2007, 80% in 2008, 90% in 2009 and 100% in 2010).

conditions of introducing the SPS in the NMS are laid down in the 1782/2003 Council regulation (which was amended several times in the last few years). After several negotiations between the European Commission (EC) and the Hungarian Ministry of Agriculture, Hungary plans to introduce a so-called quasi hybrid version of the SPS. This version is a mixture of the regional and the historical SPS model. Farm specific payments will consist of two parts: (1) a regional component, which is a decoupled area payment, and (2) an additional component, which is based on historical entitlements.

Since the EU accession in 2004, AKI has been conducting several impact analyses regarding the introduction of SPS under different conditions. During this work it was proven, that structural changes in the agriculture can not be estimated properly with a sector model like HUSIM. Thus we decided to use farm groups as model agents in FARM-T. Applying farm groups instead of a farm- or sector level approach has many advantages. On the one hand, by aggregating farm level data, the model becomes less biased by possible errors in the underlying dataset. On the other hand, the introduction of farm groups gives us a detailed view of the investigated sectors, and makes it possible to take the underlying farm structure into account.

In order to estimate the possible effects of decoupling direct payments from production (which is one of the new elements of the SPS), we combined the farm group level approach of FARM-T with a microeconomic approach. Thus, we perform a microeconomic analysis on the base year's data set to estimate the effects of decoupling on producers' decisions (see Section 3.4).

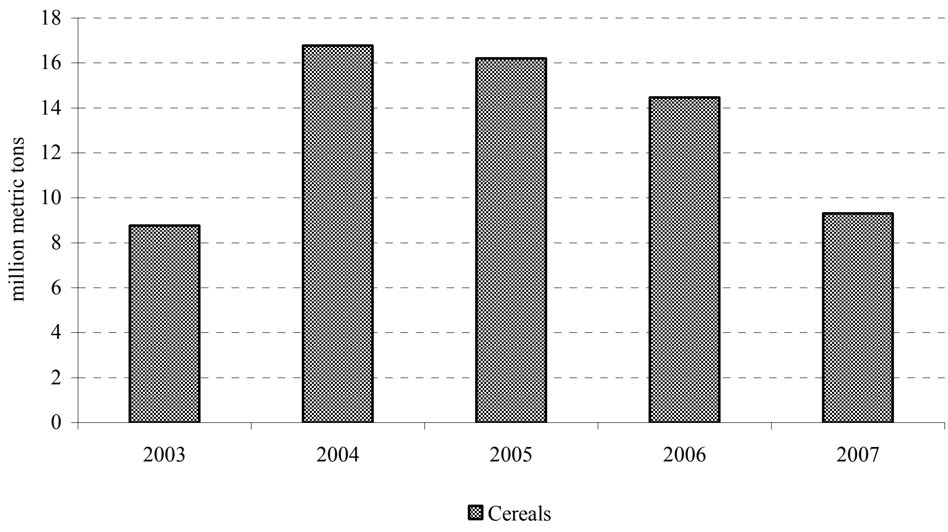
2.2. Increasing cereal stocks

When FARM-T was created in 2004-2005, increasing intervention stocks and growing surpluses characterized the cereal market. In 2004, as a result of the favourable weather, a record of 16,78 million tons of cereals were harvested. The next two years brought similarly good yields in the cereal sectors. These extraordinary good harvests led to serious problem in the cereal market. The lack of adequate storage capacity, and problems in the logistic network led to a high domestic supply, which pressed down producer prices well below the intervention price level, in 2004/2005. The government answered with an instant storage building program, and cereal intervention stocks grew rapidly. The opening intervention stock in the 2006/2007 cropping season reached 7 million tons.

That time, it was an important issue for us to estimate the effects of various policy scenarios on cereal stocks and prices. To meet this demand, we had to make the domestic cereal producer prices in our model endogenous. To do so, a price adjustment method was created. It adjusts original exogenous prices according to actual cereal stock levels, and to other endogenous variable changes (see Section 3.1).

Since then, the situation has dramatically changed. Drought in summer 2007 led to a weak maize harvest in autumn (Figure 1), which prevented cereal stocks from growing further. Long-lasting high producer prices and the increasing cereal transportation on trucks, made cereal export expand to a great extent. As a result, by the beginning of the 2007/2008 cropping season, intervention stores were nearly empty. At the end of 2007, thanks to high producer prices and the favourable perspectives of ethanol production from maize, cereal producers in general have great prospects for the future.

Figure 1: Cereal production in Hungary (2003-2007)



Source: Central Statistics Office (CSO), Hungary

3. Methodological overview of FARM-T

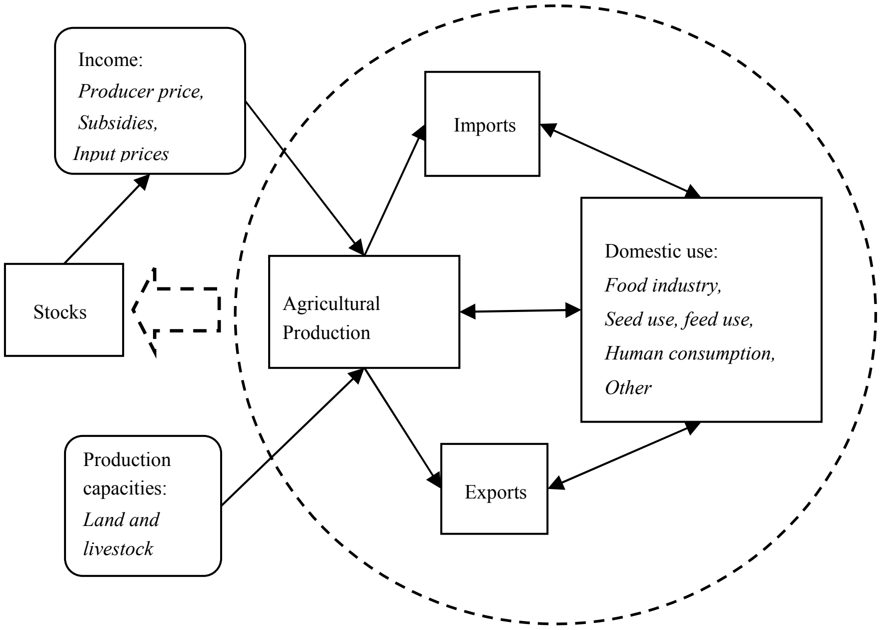
FARM-T is a partial equilibrium, multi-commodity econometric model. It is mainly used for performing policy impact analyses in the context of EU and country level agricultural policies. FARM-T is a one-country model, i.e. it is built by taken the local circumstances in Hungary into account therefore its results are only relevant for this country. During the model development, we relied upon our experiences with the already existing HUSIM, which has been applied as a main tool for policy analyses in the AKI since the late 1990's. These two models are normally applied simultaneously under the same policy and macroeconomic assumptions.

The commodities covered by the model are selected to represent only the major agricultural products in Hungary. Crops include wheat, maize, barley, sunflower seeds and rapeseeds. Livestock production consists of beef and veal, pork, broiler, sheep and milk. The model is dynamic in a recursive manner, as it produces projections for a given year via an iterative process. Starting from a selected base year, the model uses results of the previous iterative steps to make projections for the investigated year.

The supply side of the agricultural production is represented by farm groups. Here, farm groups are the resulting sets of a classification process which is performed on the selected base year's FADN data set. The aim of this classification is to build up groups from individual farms which are similar according to their activity profile. As a result, every farm group represents a particular activity profile, and acts as a single model agent. Under the assumption that they follow rational behaviour and have complete knowledge of input and output markets, farm groups maximize their income by allocating the available land between crops and by adjusting the output levels of animal production.

Demand and supply sides of the processing industry are determined by Cobb-Douglas functions. Human consumption is given by consumption functions. Seed use is connected with actual land use, and feed use is determined by animal production. The determination of exports and imports is fairly complex; foreign markets are regionally differentiated, and a price comparison method is also applied to take competitiveness of Hungarian products on foreign markets into account. Stocks are calculated in the balance sheets as residual values (more on reaching an equilibrium state, see Section 3.3). Stocks affect the following year's producer and input prices via a price adjustment method, which adjusts prices according to actual stock levels and other endogenous variables (Figure 2).

Figure 2: Operation of the FARM-T model



Source: Udovecz et al., 2006

After describing the general structure of FARM-T, we go into the details about supply and demand sides, and how equilibrium is reached.

3.1. Supply

The supply side of the agricultural production is represented by farm groups. Farm groups are created by classifying the Hungarian FADN data set of the chosen base year. Currently, Hungarian FADN database contains accountancy and production specific data of about 1.900 individual farms. Before classifying these farms, we filter out those that do not fit into the model structure. Either small sized family farms that do not appear on the market, or farms with activities outside the scope of the model, are filtered out. First, the agricultural area is analysed, than the size of animal production is specified. Farms with only pasture land or horticulture, and farms with only small sized animal production are sorted out in the first step (Table 1).

Table 1: Constraints regarding minimal animal production in FARM-T

Activity	**Constraint (minimal level)**
Milk production	10 cows
Beef and veal production	3 suckler cows
Bull fattening	1 head
Sheep meat production	10 ewes
Pig fattening	10 pigs
Broiler production	100 heads

Source: own table

In the case of the 2005 FADN database, 1.670 farms were chosen from the total of more than 1.900. In the next step, individual farms with the same commodity coverage were grouped together into 36 farm groups (the actual number of farm groups depends on the base year data). The farm groups' production costs, yields, and output levels were calculated from the farm level data, by applying a weighting system derived from the original FADN weighting scheme. All individual farms become a unique weight inside the farm group, and every farm group represents a unique share in the total agricultural output. Total sector level output is calculated by simple aggregation of the farm groups' output levels.

Total sector level output in the agriculture is determined as the sum of sectoral outputs of the different farm groups. Farm groups follow a profit maximizing behaviour, which is described in the model as a complex optimization problem. The precise formulation of the objective function is as follows:

$$\max_x \sum_{i \in I} \left[\sum_{j \in J} \left(FH_j^i \cdot x_j^i \right) + DS^i - GC^i \right],$$

where:

- Denote I the set of farm groups and J the set of activities
- x_j^i is the output level of the activity j in the farm group i (area harvested, livestock production in live weight or milk production)
- DS^i is the sum of direct subsidies in farm group i, which can not directly be connected to any modelled activities
- GC^i is the sum of fixed costs of the farm group i.

FH_j^i is given by the following equations:

$$FH_j^i = pp_j \cdot y_j^i + dp_j - vc_j^i,$$

where:

- pp_j is the producer price of the commodity j
- y_j^i is the yield of the activity j in the farm group i
- dp_j is the sum of direct payments that are connected to the activity j under the investigated policy scenario
- vc_j^i is the variable cost of the activity j in the farm group i

Variable and fixed costs of the different farm groups and the DS^i direct subsidies in the base year are calculated as weighted averages of the farm group members. Total production cost of a given sector is divided into several categories and each category is forecasted separately. In order to estimate future values of different cost categories, the macroeconomic circumstances have to be forecasted with several key variables (e.g. consumer price index, oil prices). There is also a connection between land rental prices and area based payments in the investigated agricultural support systems (i.e. SAPS, SPS).

The pp_j domestic producer prices are calculated by adjusting external producer price projections of selected reference prices. The adjustment is made via regression functions. The parameters are estimated using historical data from the period 1995-2006. Determining of producer prices the following effects are taken into account: (1) the connection between domestic and foreign market prices, (2) interrelationships between different sectors that affect producer prices, and (3) the effect of increasing or decreasing stock levels on producer prices. Domestic producer prices are calculated as follows:

$$pp_j = f_j(xp_j, nv_k),$$

where:

- xp_j is the exogenous price projection of the commodity j
- nv_k, $(k \in K_j)$ is a defining endogenous variable of the activity j (K_j is the set of all such variables, see Table 2)

Among crop products, maize has a special role. By the price adjustment process, maize was used as a 'leading crop', i.e. the price of maize affects the prices of other crop products in a direct-, or an indirect way (Table 2).

The unit producer prices, i.e. prices per hectare or per ton are also affected by the yields. The y_j^i yields are calculated based on an exogenous, county level yield prognosis. Proportions of farm group level and country level yields are assumed to be constant.

Table 2: Price projection functions for crop products in FARM-T

Commodity	**Independent variables**	**Source**
Maize	1. CIF price	FAPRI
	2. Beginning stock	Endogenous
Wheat	1. Maize producer price	Endogenous
	2. Beginning stock	Endogenous
Barley	1. CIF price	FAPRI
	2. Wheat producer price	Endogenous
Sunflower seed	1. Lagged oil price (CIF)	FAPRI
	2. Maize producer price	Endogenous

Source: Own table

As we will discuss later, yields (which has an effect on producer prices per unit) and production costs of a farm group are adjusted due to the structural change that comes with the introduction of decoupling. So decoupling of direct payments has an indirect effect on producers' decisions and on total output by modifying the objective function parameters. However, decoupling has also a direct impact on output levels, because if individual farms set aside their arable land, the farm group's total harvested area decreases, which implies a diminishing output level.

The farm groups' optimization problem contains the following constraints, regarding the output levels x_j^i:

$$\left[\frac{(1-\delta)E_j Ch_j^i}{100}+1\right]\bar{x}_j^i \le x_j^i \le \left[\frac{(1+\delta)E_j Ch_j^i}{100}+1\right]\bar{x}_j^i, \text{ if } Ch_j^i \ge 0$$

and

$$\left[\frac{(1+\delta)E_j Ch_j^i}{100}+1\right]\bar{x}_j^i \le x_j^i \le \left[\frac{(1-\delta)E_j Ch_j^i}{100}+1\right]\bar{x}_j^i, \text{ if } Ch_j^i < 0\,.$$

- $\bar{x}_j^i > 0,$ is the initial level for activity j of farm group i
- Ch_j^i is the percentile change of income per unit divided by production cost per unit
- $E_j > 0,$ is the elasticity of supply of the activity j, calculated using time series data
- $\delta > 0,$ is a constant, that enlightens the competition of sectors for the available resources (e.g. arable land)

$\left(\frac{E_j Ch_j^i}{100}+1\right)$ is the usual response to a change in the income situation, determined by the elasticity E_j. Multiplying the first term with $(1+\delta)$ and $(1-\delta)$ respectively, an interval is pointed out for the production decision. The size of δ determines the possible magnitude of the farm group's reaction. δ is usually set to be greater than the maximum of the elasticities: $\delta > \max_{j\in J} E_j$. This makes possible to increase production, in order to maximize profit, even if the income per cost ratio decreases ($Ch_j^i < 0$), or vice versa.

Beside the above constraints on the magnitude of farm group reactions, some other commodity specific-, and global constraints are applied – e.g. total agricultural land available, direct payment quotas. These additional constraints allow us to simulate competition between crops for the available arable land, or to measure the effect of quotas on producers' decisions. With the intended introduction of the SPS scheme in 2009, compulsory set aside comes into force, which can have a moderate negative effect on the size of the harvested area of arable crops. This concept is incorporated into the model structure as an additional constraint on the x_j^i harvested areas, which prescribes that a given portion of the total arable land is set aside.

The part of the food industry that is directly connected with the modelled agricultural commodities is also covered by FARM-T. The supply of the food industry is determined by production functions with econometrically estimated parameters. The variables include procurement prices, changes in human consumption, consumer preferences, and raw material production. Both domestic- and imported agricultural products can be processed, what implies different raw material costs and food prices for a given commodity. Different food prices induce different demand for consumption, this way modifying the proportion of domestic and imported raw materials used in the processing industry.

3.2. Demand

On the demand side, there are human consumption, seed- and feed use, demand of the food industry, and other industrial use (e.g. bio-ethanol production). Human consumption is driven by food prices, real income and trends, and is divided into domestic and import consumption. The difference between them is that domestic consumption is influenced by the domestic food prices, while import consumption is determined by import prices. Seed use depends on the size of the arable land in use, and the crop allocation, because every crop culture has a unique demand for seeds.

Feed use is determined by the output levels of livestock sectors, which binds animal- and crop production together. The initial value of the demand of food industry is derived from the production functions, but this initial level can change, while reaching the equilibrium state (see Section 3.3). Other industrial use is fully determined by experts' evaluations, and is set to a proportion of total output, or to an absolute value. An example for this latter case is the incorporation of the increasing bio fuel production into the FARM-T. The expected demand of ethanol production from maize was estimated by investigating the capacity of the announced bio fuel projects, analyzing the maize market, and taking into account the maximum available quantity that can be passed to the industry.

3.3. Equilibrium

After calculating supply and demand, the model uses commodity balance sheets to reach the equilibrium state. A balance sheet contains a system of equations describing the equilibrium of each commodity market. Logical functions are applied to solve this system of equations automatically. These functions describe the interrelationships between agricultural sectors (e.g. raw material- or feed demand connections), and compare world market prices to export- and import prices. This comparison between prices models the competition of Hungarian agricultural commodities on foreign markets. Balance sheet equations are as follows:

$$\sum_{i \in I} x_j^i + IM_j + ST_j^0 = \sum_k \left[ID_k \cdot km(j,k) \right] + EX_j + SU_j + FU_j + HC_j + ST_{j,} \quad \forall j \in J.$$

- IM_j is the import of commodity j
- $km(j,k)$ determines how many units of the raw material j are used for producing the commodity k
- EX_j is the export of commodity j
- SU_j is seed use for activity j
- FU_j is feed use of commodity j
- HC_j is human consumption of commodity j
- ST_j^0 and ST_j are the opening and ending stock levels

Opening stocks are derived from base year data, or equal to the ending stock of a previous iteration step, adjusted by stocking loss. Ending stocks are calculated as residuals, when the other terms of the equations have already been determined. Exports and imports are calculated by investigating foreign market prices and determining the quantities available for export, or necessary to fulfil all the demand. Domestic use is derived from human consumption, seed- and feed use, and industrial use. Export markets are regionally differentiated by transport modes and distances (**Table 3**). Several export markets are connected to a given commodity, each market having a unique market price, transportation cost, and size (maximum quantity that can be placed on the market). This is necessary to measure the effect of changing export potentials on commodity balances.

Table 3: Regionally differentiated foreign markets in FARM-T

Commodity	**Number of foreign markets**
Wheat	4
Barley	2
Maize	6
Sunflower seed	1
Rapeseed	1
Pig	5
Broiler	3
Beef and veal	3
Milk	3
Sheep	6

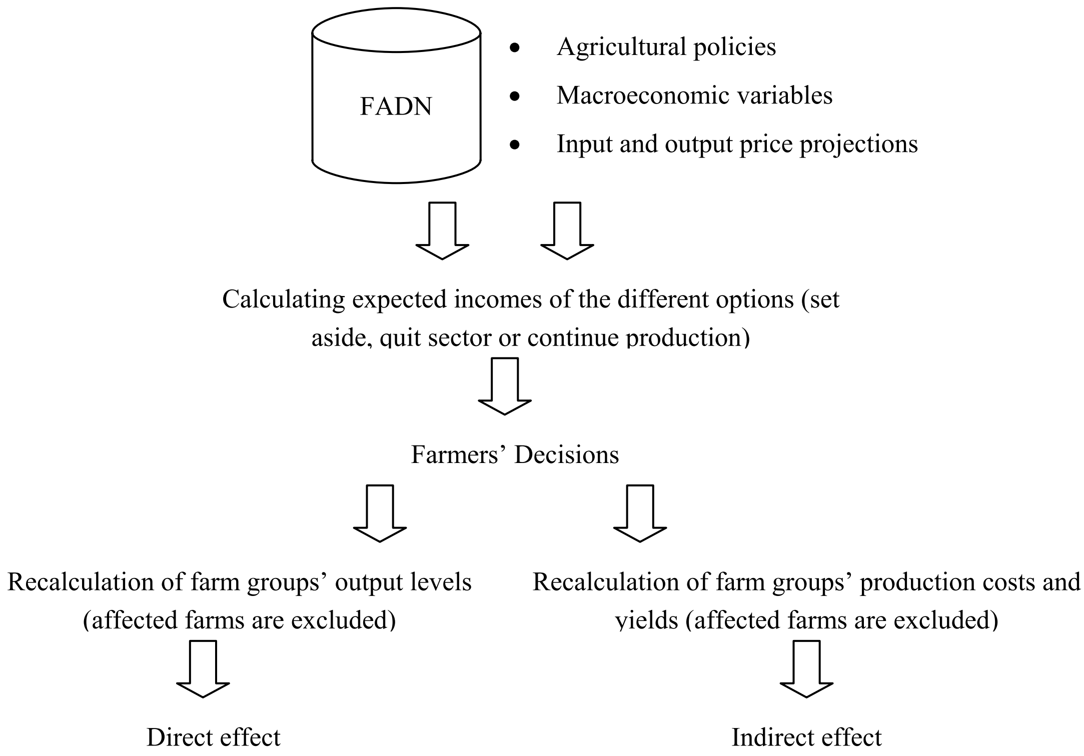
Source: own table

3.4. Decoupling of direct payments from production

The 2003 CAP reform came with some new elements in the applied agricultural support schemes. In eight of the new member states, SPS will only be introduced after a transitional period, during which SAPS is applied. One key element of the reform is the decoupling of direct payments from production, which was intended to help farmers to be more competitive by allowing them to freely alter their production to suit demand. This naturally has an impact on agricultural output levels. Following the OECD terminology, effects of decoupling can be identified as static, dynamic, or risk related (OECD, 2000). FARM-T focuses on commodity markets, and their balances, and can easily deal with static effects of decoupling. Dynamic effects, especially changes in investment patterns or long term expectations, are beyond the scope of the model. In the current model version, producers' expectations cover only the one year, so investment decisions depending on mid- and long term prospects are not incorporated into the optimization method. Concerning risk related effects (insurance and wealth effects), neither changes in producers' risk aversion patterns, nor changes in income stability, are taken into account.

In order to model the complex effect of decoupling of direct payments on farm structure and output levels, we have decided to combine the macroeconomic view of FARM-T with a microeconomic approach. At first, effects on output levels are estimated regarding every individual farm, and then these effects are aggregated at farm group level. Not only the effects on output levels are calculated, but the structural changes that decoupling causes are also taken into account. Setting aside land, or decreasing animal production in farm level, changes the structure of the farm groups. If an individual farm adjusts its output levels, than not only the aggregated output level, but also the group's inner structure will be affected. This is because the weights of the individual farms are adjusted according to the change in output levels. Changes in output levels of individual farms also modify the aggregated production costs and yields of the farm groups. By changing production costs and yields, decoupling modifies the objective function parameters of the farm groups' optimization problem, and so affects total agricultural output in an indirect way (Figure 3).

Figure 3: Microeconomic analysis of farm group level effects of decoupling



Source: Own figure

In the case of crop production, decoupling direct payments from production gives producers a new option: allocate the available land freely between eligible crops, or even earn area payments by setting aside land. In our microeconomic analysis the possible income of setting aside land is compared to the projected income of using land for crop production. The decision of the farmer is very simple: the activity with the greater expected income is chosen. Theoretically, we made an explicit assumption on producers' decisions, that they follow income maximizing behaviour. The expected income of setting aside land equals to the area payment minus the costs of keeping land in good agricultural and environmental conditions, minus the accounted amortization on existing assets. Keeping land in proper conditions is a prerequisite for getting area payments, so the expenses incurred with it have to be taken into account. In FARM-T these expenses are calculated based on land rental prices, fixed costs, and wages.

After comparing expected incomes, farmers decide either setting aside land or continue normal production. After farmers' decisions have been made, a correction is conducted to keep agricultural area with above-average soil and climatic conditions cultivated. Production costs and yields at farm group level are then recalculated based on only those members' FADN data, who continue production.

In the case of animal production we compare variable costs to total revenue. The idea behind is that if farmers are not even able to cover variable costs of production, then they are facing bankruptcy, and thus decoupling is an incentive to quit the investigated sector. This impetus is based on the concept of decoupling, which enables farmers to get subsidies based on historical entitlements, without the need of continuing production. In order to simulate this decision, variable costs have to be projected for the investigated period. As decoupling in animal sectors in Hungary is only partial, total revenue also includes coupled direct payments. Since some members of the farm group may quit the sector, farm group level production cost and yield have to be recalculated as described above in the case of crop production.

4. Summary

In this paper we introduce the modelling work at AKI in the past decade and describe our latest modelling tool FARM-T in details. In the first part, we give some historical background information about the antecedents of FARM-T and the role of AKI in supporting policy decision makers in the period around the EU-accession. Then we discuss issues that determined the directions of the model development. These include the introduction of the SPS in Hungary, and special market related issues, especially the problems on the cereal market between 2004 and 2006.

In the third and longest part of our paper we introduce FARM-T in detail. After describing the general structure of the model, we focus on the supply side, especially on how agricultural production is represented by farm groups. Then we also discuss the structure of the demand side of the model, and finally, we describe how the equilibrium of the commodity markets is set by solving balance sheet equations. At the end of the paper, the microeconomic approach is presented, which is applied to deal with the concept of decoupling of direct payments from production.

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